E907 Cherenkov Digitization Algorithm

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Abstract

This note documents the algorithm used to simulate the response of the E907 Cherenkov counter in the experiments detector simulation. It is current as of February 18th, 2009, code release X.Y.Z.

1 GEANT Hits

2 Hits to photo-electrons

Each GEANT hit represents a segment of a track and is projected forward until it hits a single mirror. The number of photoelectrons produced in the PMT assigned to that mirror is calculated as

$$N_{\mathrm{PE}} = r_{\mathrm{T}} r_{\mathrm{C}} \int_{\lambda_1}^{\lambda_2} \int_{\lambda_1'}^{\lambda_2'} \epsilon_{\mathrm{PMT}}(\lambda') w(\lambda, \lambda') N(\lambda) d\lambda' d\lambda, \qquad (1)$$

where λ is the wavelength of Cherenkov photons produced by the particle, w is a function which represents the efficiency of the pTP waveshifter to absorb a photon at wavelength λ and reemit it as wavelength λ' and ϵ is the efficiency of the PMT to yield a photoelectron from an incident photon of wavelength λ'. The constant r_{C} varies from mirror-to-mirror and represents the relative efficiency of the mirror in question to the central mirror number 17. The value of this constant is taken to be the calibration constant "xxx" from the calibration database table "XXX". The final constant r_{T} is tuned to match the overall light levels in the Monte Carlo to the data. Additional documentation on each of these factors is provided below.

2.1 N_λ

The number of Cherenkov photons per unit wavelength is computed from the standard formula for Cherenkov radiation

$$N(\lambda) = \frac{2\pi\alpha z^2}{\lambda^2}\left(1 - \frac{1}{\beta^2 n^2(\lambda)}\right) ds\, d\lambda, \tag{2}$$

where α is the fine structure constant and the particle considered makes a step of size ds[cm], has charge z [in units of e], and has speed βc. The index of refraction for the CKOV gas (C_4F_{10}) is assumed to follow a Cauchy parameterization

$$n(\lambda) = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + ... \tag{3}$$

The parameters $A, B, C...$ were determined to be

$$
\begin{aligned}
A &= 1.00131398, \\
B &= 8.76386 \text{ nm}^2, \\
C &= -4820.94 \text{ nm}^4,
\end{aligned}
\tag{4}
$$

from a fit to data plotted in []. Only the first three terms in the expansion were required to get a very good fit across the wavelength of interest (100 to 600 nm).

2.2 $w(\lambda', \lambda)$

The PMT's used in the CKOV are coated with the waveshifter p-terphenyl (pTP) [?,] The absorption and emission spectra for pTP were taken from [?,]nd [?,] The absorption data is well described by two guassians centered on $\lambda = 190$ mn and $\lambda = 275$ nm.
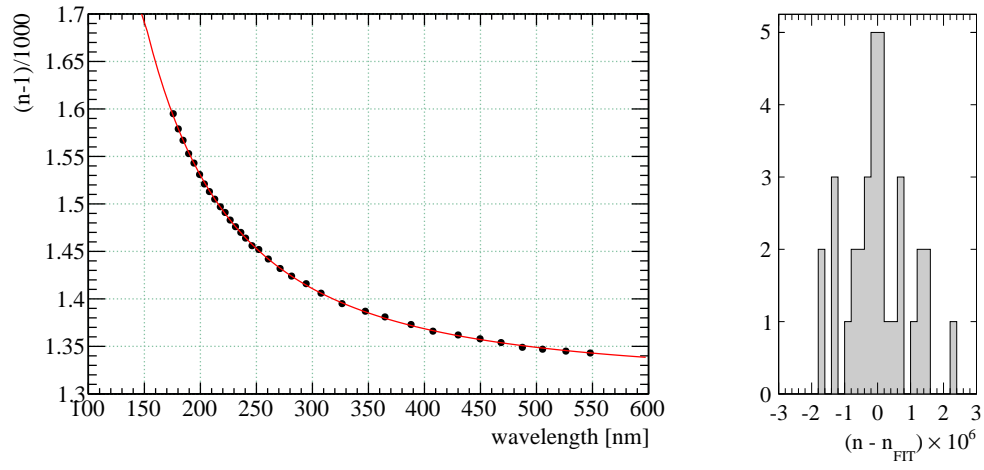
3 Tuning to data

Figure 1: Left: The index of refraction in C_4F_{10} points were read of a plots from []. The red curve is the parameterization from Eq. 4. Right: The differences between the points and the parameterization. The parameterization reproduces the points to within 2 parts in a million.
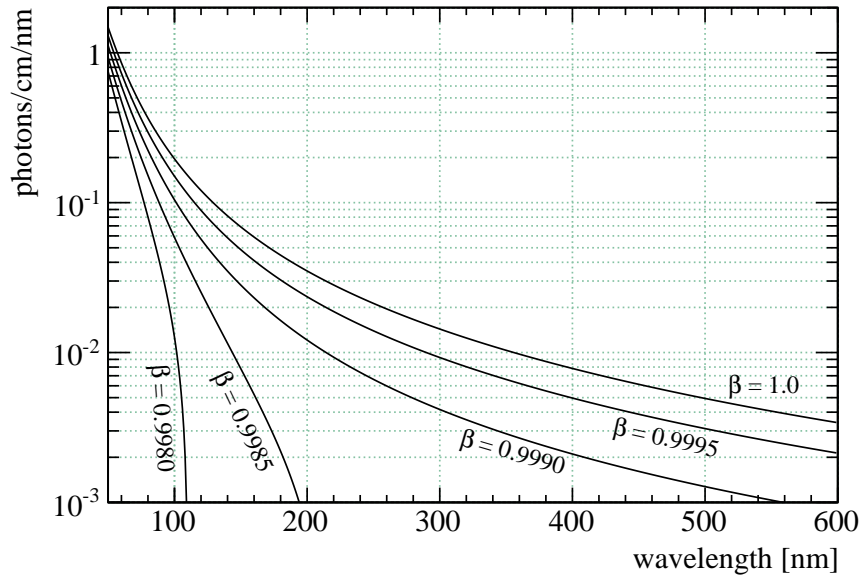
Figure 2: The number of Cherenkov photons produced per cm per nm for particles with β's between 0.9980 and 1.0. Threshold is roughly 0.9985 when the number of photons produced near 200 nm goes above zero.
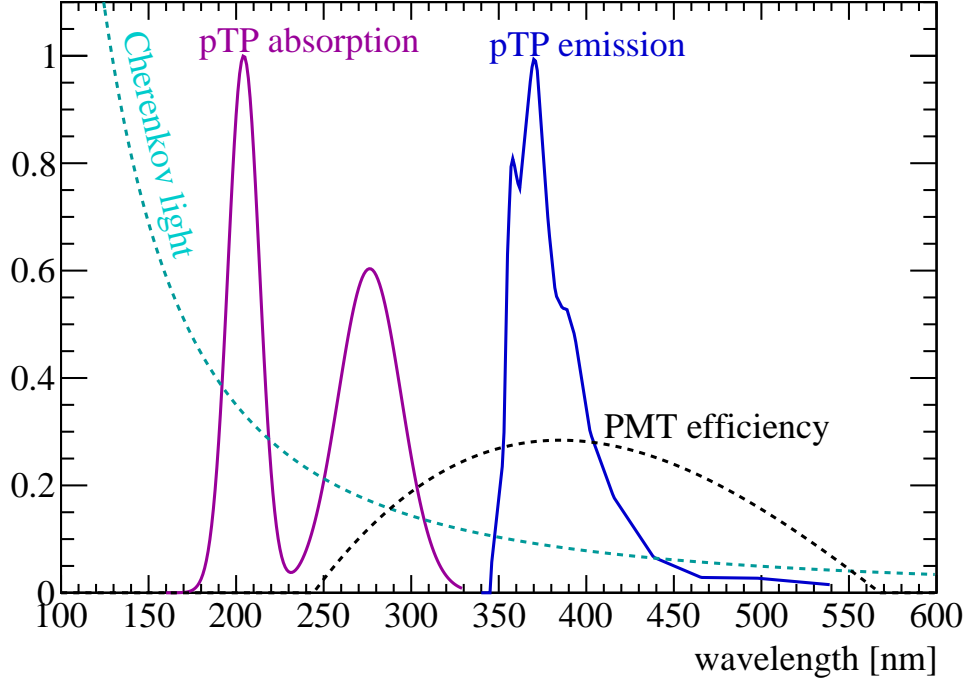
Figure 3: Summary of photoelectron production in the CKOV. The number of Cherenkov photons generated per cm per nm by a $\beta = 1$ charged particle is shown by the cyan dashed curve. This is absorbed by the pTP wave shifter according to the purple curve. This light is reemitted according to the blue curve. The efficiency of the PMT is shown in the dashed black curve.
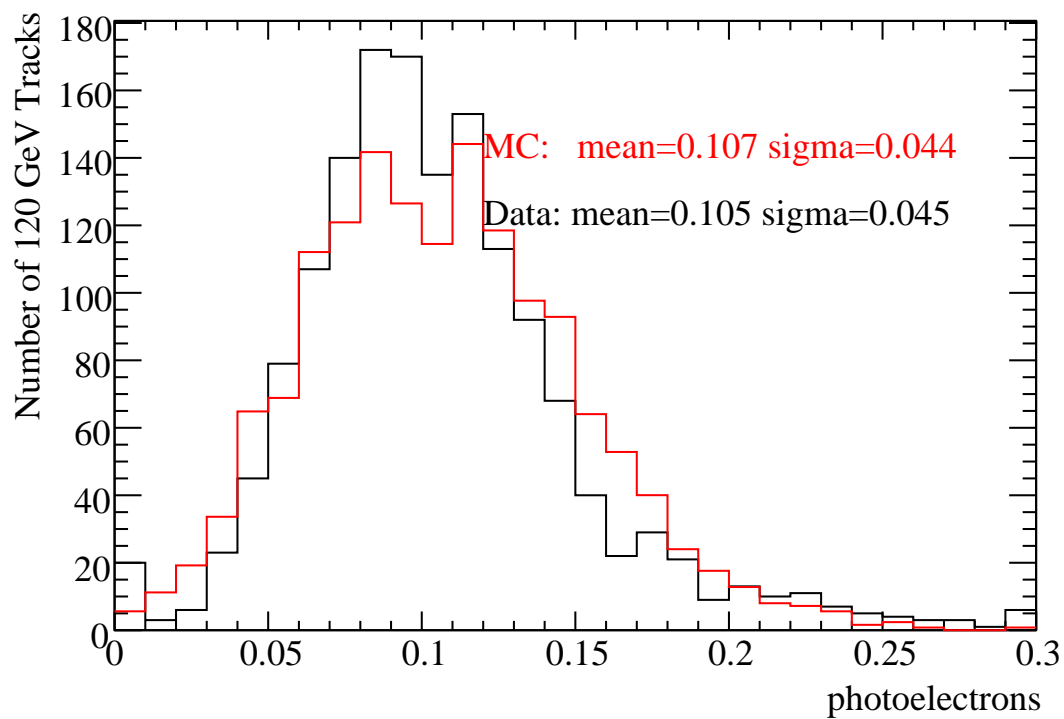
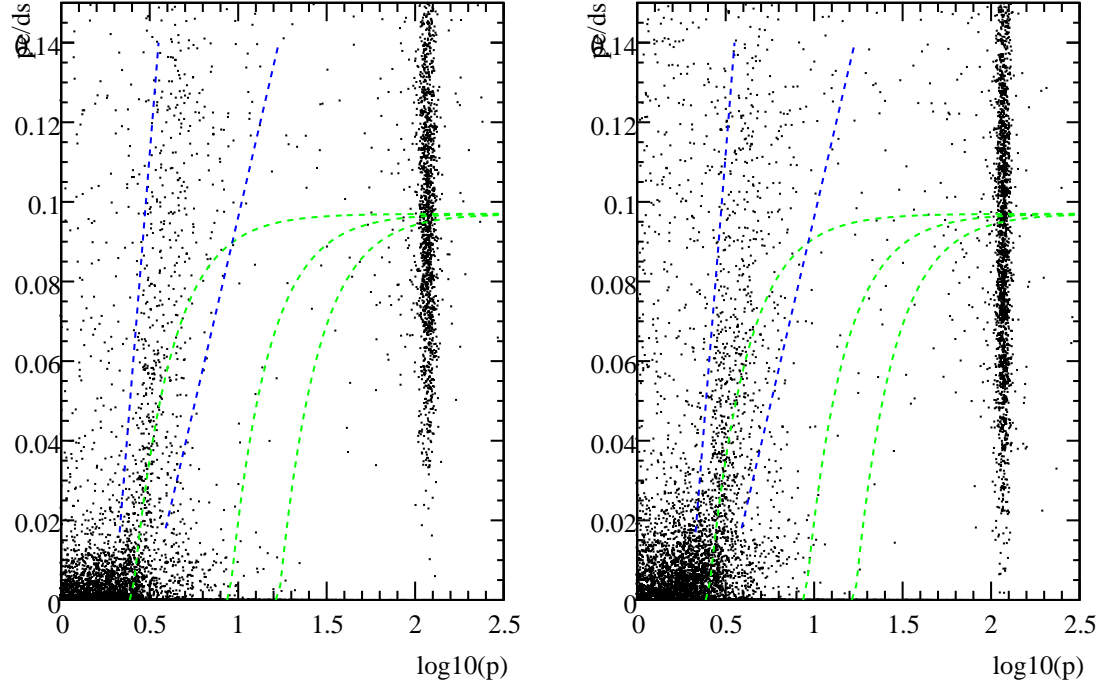Figure 4: Comparison of photoelectron yield per cm for 120 GeV tracks. Data in black, MC in red.

Figure 5: Comparisons of photoelectron yield per cm for data (left) and Monte Carlo (right) as a function of track momentum. Expected curves for π, K, and p are shown in green. The blue lines are for reference to aid in comparing the two plots.